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REVIEW OF G. I. SKANAVI'S BOOK, "THE PHYSICS OF DIELECTRICS"

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In 1932, a group of scientists at the Leningrad Physicotechnical Institute published a monograph, "The Physics of Dielectrics," which sought to cover all four branches of the physics of dielectrics, namely, dielectric polarization, dielectric losses, electric conductivity, and breakdown of dielectrics.

However, in the past 18 years, under the influence of the intensive development of the USSR electrical and radio industries, many new findings have been made in respect to the behavior of dielectrics, especially in weak electric fields (i.e., prior to breakdown). The changes in theory made necessary by new discoveries are covered by Professor G. I. Skanavi, Doctor of Physicomathematical Sciences, in his new monograph, The Physics of Dielectrics (Fizika Dielektrikov, Gostekhizdat, 1949, 500 pp, 24.15 rubles).

Skanavi's book consists of four chapters.

Chapter I discusses the processes of establishing a stationary field in a two-layer dielectric when external ac and dc voltages are applied to it. These processes are very important in examining the formation of high-voltage polarization, in estimating residual current, and in treating other problems.

Chapter II, containing 19 sections, treats dielectric polarization, a field in which the author has obtained very valuable results. It is probably due to this latter circumstance that polarization is treated in more detail than, for instance, the conductivity of dielectrics. In a new approach to phenomena associated with dielectric polarization, the author, after stating the elementary processes of polarization and methods of calculating molecular constants, attempts to calculate effective and internal fields and to establish the relation between molecular and dielectric constants. Among the new features is an explanation of polarization on the basis of the shift of an ion from one equilibrium position to another. This concept, called the theory of thermal ion

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polarization, was developed by the author. A separate section is devoted to polarization caused by weakly bound ions and dipolar molecules. Such a separation seems questionable to us, since it might lead to the impression that polarization of elastically bound polar molecules, which is discussed in the previous section, is not dependent on thermal motion.

Section 8 describes experiments on the polarization of nonpolar liquids, comparing experimental results with theoretical conclusions and devoting attention to the works of P. A. Zilov and I. I. Kosonogov, who were the first to obtain quantitative data on the dielectric constants of many nonpolar liquids.

Sections 9 and 10 give a theoretical interpretation of polarization of depolar liquids. After noting the admissibility of Onsager's theory for many liquids, the author points out its shortcomings and the desirability of a more rigid theory. In his statement of the theories of Kirkwood and Debye, Skanavi points out that the work of A. I. Ansel'm has led to radical changes in Debye's theory.

The subsequent sections explain dielectric polarization in solids. The author's theoretical determination of the temperature coefficient of the dielectric constant of ionic crystals is interesting. He also discusses substances with high dielectric constants which do not belong to the piezo electric category (rutile and perovskite-type crystals). He analyzes the cause of a high dielectric constant and gives his own theoretical interpertation, which is in good agreement with experimental data. Another section treats problems relating to the possible rotation of dipole groups in crystal lattices and polarization phenomena in glass. These problems are concisely stated, but unfortunately, it seems that all available experimental material was not used here.

Section 11 examines piezoelectric phenomena. After a short exposition of results obtained with Rochelle salt and potassium acid phosphate crystals, Skanavi turns to research on barium metatitanate. This new type of piezoelectric substance, discovered by B. M. Vul', Corresponding Member, Academy of Sciences USSR, had been studied actively by the author. Phenomena associated with barium titanate polarization are treated in detail.

Chapter III, consisting of 10 sections, treats ionic electrical conductivity but does not take up electron conductivity with the exception of a few references to the electron current appearing in crystalline dielectrics in the presence of strong electric fields. This chapter, though covering all the basic questions pertaining to ionic conductivity, does not always do so in sufficient detail.

A very interesting section discusses the ionic conductivity of liquid dielectrics, including a theoretical derivation of the law which states that the product of the viscosity of a liquid and its electrical conductivity remain approximately constant. This section provides a theoretical basis for the following sections on the ionic conductivity of solid dielectrics, which are quite different from those found in other books on dielectrics. Under the influence of the excellent work of A. F. Ioffe and his school, problems connected with high-voltage polarization have gained an important place in the investigation of the conductivity of solids dielectrics. Skanavi places high-voltage polarization phenomena at the end of a separate section (Secondary Phenomena Associated With the Passage of a Current through a Solid Dielectric), following an exposition of the basic phenomena of dielectric conductivity. The author then turns to the problem of electrical conductivity in strong fields, explaining the increase in conductivity with field intensity by the fact that the work done by the field in the ion's path is equal to the energy of thermal motion. This concept supplies a possible theoretical basis for the empirical formula of Poole. It should be noted that Skanavi is somewhat inconsistent on p 313 in explaining the decrease of Poole's constant with temperature by a decrease in the

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space charge, because the electrical conductivity increases with the field and Poole's constant decreases with temperature, even at temperatures characterized by a virtual absence of space charge. In these instances, the decrease in Poole's constant simply follows from formula (3.39) in the book.

The remaining material in this chapter is also presented in accordance with modern views. Deserving mention are the author's ideas concerning difficulties which arise in explaining the break in the straight line (expressed in logarithmic coordinates) which expresses the dependence of conductivity on the reciprocal of temperature on the basis that another basic ion in crystal lattice begins to move (p 287). Skanavi gives very thorough coverage to problems connected with the mechanics of ionic conductivity in crystals, but in some places the text is not clear due to occasional lack of proper attention to symbols. The results of experiments on the conductivity of glass and ceramics -- a field in which basic work has been done by Soviet authors -- are treated fully.

Chapter IV deals with dielectric losses.

Section 1, starting from the results of Chapter II, is devoted to the establishment of polarization when a voltage is applied or removed and to the calculation of relaxation time and the magnitude of absorption current. The author develops his general theory of dielectric losses on the basis of an examination of the simplest relaxation process for dipoles or weakly bound ions, without cumbersome mathematical computation, leading to the correct basic formulas for the dependence of ε and tg δ on frequency and temperature. The book correctly points out that in some cases experimentally obtained dependences of the loss angle on frequency do not agree with those obtained by general theory. The author points out that a formal theory agreeing with any experimental results may be obtained by increasing the complexity of the function of drop in absorption current with time; however, the importance of this fact should not be overrated, since formal theories naturally can not explain the relation between dielectric losses and molecular structure.

In succeeding sections Skanavi discusses dielectric losses in dielectrics which are in different aggregate states. Through simple computations he proves that in the absence of discharge losses in gases are very low; thus, for low voltages, gases are good dielectrics. Sections 5 and 6 discuss dielectric losses in nonpolar and polar liquids. Section 7 treats data on dielectric losses in solid inorganic crystals and shows that they are mainly determined by conductance (in some cases these phenomena are complicated by formation of a space charge), and that relaxation processes can scarcely be expected. It is only in a footnote that Skanavi refers to recent research on phlogopitemica, gypsum, and rock salt, in which there are losses different from conductance losses. The section then discusses losses in inorganic glass. In his theoretical interpretation of losses in glass at high frequencies, the author gives his calculations for the relaxation time of ions of admixtures when they move in a closed field in glass. He also gives numerous experimental data, mainly from Soviet authors, concerning the dependence of the dielectric loss angle on composition of the glass, temperature, and frequency. He bases his qualitative explanation of these phenomena on the concept that glass is an irregular 3-dimensional grid, but he points out the possibility of an explanation from the viewpoint of Lebedev's crystalline hypothesis only in reference to the neutralization effect established by Skanavi himself.

In the next section, he discusses his idea of relaxation polarization and losses in polycrystalline specimens of rutile. This new type of polarization of solid dielectrics gives rise to a very high dielectric constant (ε) at power and audio frequencies. The experimental data cited makes it possible to find the relaxation time by using the relaxation theory. Other experimental data is cited on the dependence of the dielectric losses in various ceramic materials on a number of factors, including quantity of admixtures, temperature, frequency, and humidity. This data is primarily of interest as reference material.

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Section 10 states the results of research on losses in organic substances which do or do not contain polar groups. Skanavi finds that in the latter case, the losses in pure nonpolar polymers, or those plasticized by nonpolar plasticizers, were small. Losses for substances containing polar molecules are considerably larger, having characteristic frequency and temperature dependencies of the loss angle and dielectric constant. This section also describes in detail the original work of P. P. Kobeko's school.

Section 11 discusses the dielectric losses and dielectric constants of solid and liquid dielectrics in superhigh-frequency fields. Section 12 examines dielectric losses in anisotropic dielectrics and presents in a brief form the calculation formulas for anisotropic dielectric given by Ye. V. Kuvskinskiy, with illustrations from recent experimental research.

G. I. Skanavi's work is on a high scientific level and will be extremely useful to scientific workers, engineers, and students specializing in the field of electrical insulating materials.

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